Lecture 05

Per unit (PU value)

P.U. (Per Unit value)

$$P.U. = \frac{real \quad value}{base \quad value}$$

Example: A given impedance is 0.050 per-unit on bases of Vb=138kV and S3 φ b=200MVA. Calculate Z in per-unit if base values for Vb and S3 φ b are, respectively,

a) 138 kV, 100 MVA

b) 132 kV, 200 MVA

c) 132 kV, 100 MVA

Ans:

$$Z_{pu} = \frac{Z_r}{Z_b} \Rightarrow 0.050 = \frac{Z_r}{(138KV)^2 / 200MVA} \Rightarrow Z_r = 4.761(\Omega)$$

$$(a).Z_{pu} = \frac{Z_r}{Z_b} = \frac{4.761}{(138KV)^2 / 100MVA} = 0.025(pu)$$

$$(b).Z_{pu} = \frac{Z_r}{Z_b} = \frac{4.761}{(132KV)^2 / 200MVA} = 0.05465(pu)$$

$$(c).Z_{pu} = \frac{Z_r}{Z_b} = \frac{4.761}{(132KV)^2 / 100MVA} = 0.02732(pu)$$

How to chose the base value?(S?, V?, I?, or Z?)

1. For a single phase system:

   a. Chose S_b & V_b (phase voltage)
   b. Calculate

$$I_b = \frac{S_b}{V_b}, Z_b = \frac{V_b}{I_b} = \frac{V_b^{\ 2}}{S_b}$$

2. For a three phases system:

   a. Chose S_b & V_b (line voltage)
   b. Calculate

$$I_b = \frac{S_b}{\sqrt{3}V_b}, Z_b = \frac{V_b / \sqrt{3}}{I_b} = \frac{V_b^{\ 2}}{S_b}$$

in which S_b can be transformer capacity or 100MVA, 1000KVA (easy to calculate)

Example: 一 3ϕ 12KV, 30MVA 發電機, 實際發電量 18MVA, 10.8KV, 求三相之容量與電壓標么值.

三相模式

$$S_b = 30MVA$$
$$V_b = 12KV$$

$$S_{pu} = \frac{18}{30} = 0.6(pu)$$
$$V_{pu} = \frac{10.8}{12} = 0.9(pu)$$

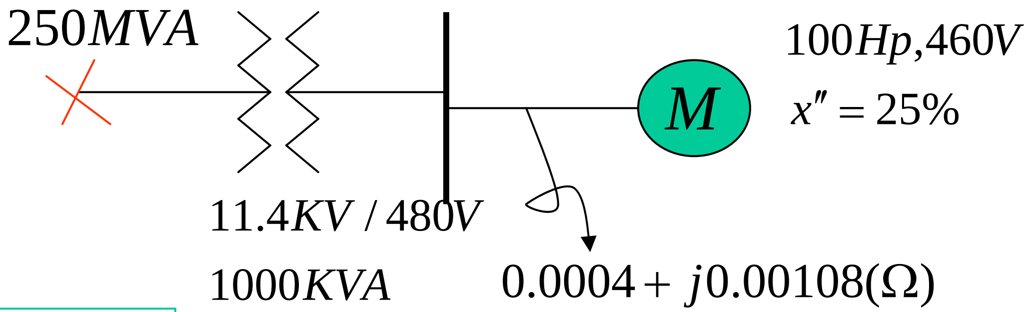
單相模式

$$S_b = {}^{30}\!/_{3}\, MVA$$
$$V_b = {}^{12}\!/_{\sqrt{3}}\, KV$$

$$S_{pu} = \frac{18/3}{30/3} = 0.6(pu)$$
$$V_{pu} = \frac{10.8/\sqrt{3}}{12/\sqrt{3}} = 0.9(pu)$$

不論採用單相或三相模式標么值均相同

example



$X_{tr}(pu)$ $x = 10\%$

Step 1: find base value

$$S_b = 1000KVA$$
$$V_b = 480V$$

$$Z_b = \frac{V_b^2}{S_b} = \frac{480^2}{1000K} = 0.2304$$

Step 2: find $Z_l(pu)$

$$R_{l(pu)} = \frac{0.0004}{Z_b} = 0.001736$$

$$X_{l(pu)} = \frac{0.00108}{Z_b} = 0.0046875$$

Step 2: find $X_M(pu)$

$$X_{M(pu)} = 0.25\left(\frac{460}{480}\right)^2 \frac{1MVA}{0.1MVA} = 2.2952$$

Step 1: find base value

$$S_b = 10MVA, V_{Ab} = 13.8KV, V_{Bb} = 138KV, V_{Cb} = 69KV$$

$$Z_b = \frac{V_b^2}{S_b} \Rightarrow Z_{Ab} = \frac{(138K)^2}{10M} = 1900\Omega, Z_{Ab} = \frac{(13.8K)^2}{10M} = 19\Omega, Z_{Ab} = \frac{(69K)^2}{10M} = 476\Omega$$

Step 2: find Real Z

$$Z_C = 300\Omega, Z_B = 300\Omega \times 2^2 = 1200\Omega, Z_A = 1200\Omega \times 0.1^2 = 12\Omega$$

Step 3: find Z pu

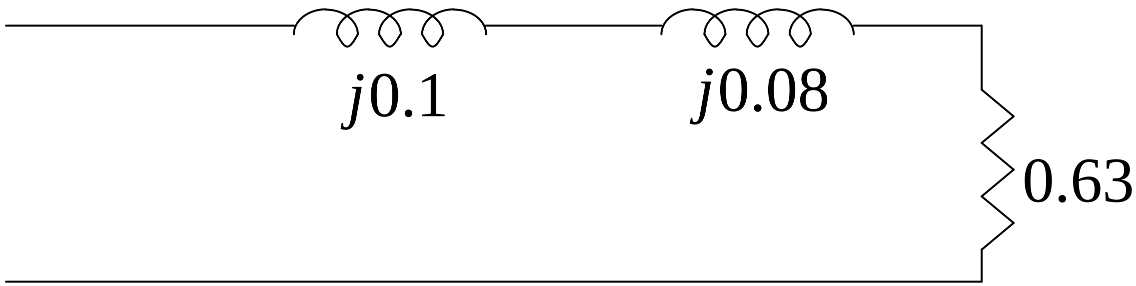
$$Z_{A(pu)} = \frac{12}{19} = 0.63$$

$$Z_{B(pu)} = \frac{1200}{1900} = 0.63$$

$$Z_{C(pu)} = \frac{300}{476} = 0.63$$

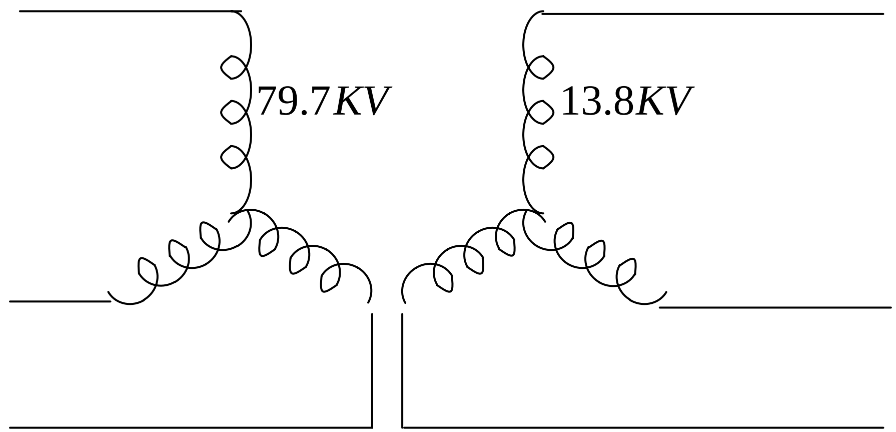
阻抗換算至各個子系統均不相同
但其標么值卻相同

上例之標么阻抗圖如下:



不需要考慮變壓器電壓比變換問題

Example: 三台 1ϕ 20/3MVA 79.7KV/13.8KV變壓器, 電抗0.2pu, 試求變壓器(a) 單相單獨使用 (b) Y-Y接線 (c) Δ-Y 接線 ;一次側及二次側等效之電抗實際值及標么值.



(a) 單相單獨使用

$$S_b = {}^{20}\!/_3\,MVA, V_{1b} = 79.7KV, V_{2b} = 13.8KV$$

$$\Rightarrow Z_{1b} = \frac{(V_{1b})^2}{S_b} = \frac{(79.7K)^2}{{}^{20}\!/_3\,M} = 952.8\Omega$$

$$\Rightarrow Z_{2b} = \frac{(V_{2b})^2}{S_b} = \frac{(13.8K)^2}{{}^{20}\!/_3\,M} = 28.57\Omega$$

一次側及二次側等效電抗:

$$Z_{1eq} = 0.2 \times 952.8 = 190.4\Omega / \, phase$$

$$Z_{2eq} = 0.2 \times 28.57 = 5.72\Omega / \, phase$$

一次側及二次側等效電抗標么值均爲: 0.2pu

(b) Y-Y 接線

$$S_b = 20MVA, V_{1b} = 79.7\sqrt{3}KV = 138KV, V_{2b} = 13.8\sqrt{3} = 23.9KV$$

$$\Rightarrow Z_{1b} = \frac{(V_{1b})^2}{S_b} = \frac{(138K)^2}{20M} = 952.8\Omega$$

$$\Rightarrow Z_{2b} = \frac{(V_{2b})^2}{S_b} = \frac{(23.9K)^2}{20M} = 28.57\Omega$$

一次側及二次側等效電抗:

$$Z_{1eq} = 0.2 \times 952.8 = 190.4\Omega / phase$$
$$Z_{2eq} = 0.2 \times 28.57 = 5.72\Omega / phase$$

一次側及二次側等效電抗標么值:

$$Z_{1pu} = 190.4 / 952.8 = 0.2$$
$$Z_{2pu} = 5.72 / 28.57 = 0.2$$

(b) Δ-Y 接線 $S_b = 20MVA, V_{1b} = 79.7KV, V_{2b} = 13.8\sqrt{3} = 23.9KV$

$$\Rightarrow Z_{1b} = \frac{(V_{1b})^2}{S_b} = \frac{(79.7K)^2}{20M} = 317.6\Omega$$

$$\Rightarrow Z_{2b} = \frac{(V_{2b})^2}{S_b} = \frac{(23.9K)^2}{20M} = 28.57\Omega$$

無論變壓器的接線情況標么值均相同

一次側及二次側等效電抗:

$$Z_{1Yeq} = 190.4 / 3\ \Omega = 63.47\Omega (\Delta \to Y)$$
$$Z_{2eq} = 0.2 \times 28.57 = 5.72\Omega / phase$$

一次側及二次側等效電抗標么值:

$$Z_{1pu} = 63.47 / 317.6 = 0.2$$
$$Z_{2pu} = 5.72 / 28.57 = 0.2$$

Example: A single-phase system similar to that shown in Fig. 2.10 has two transformers A-B and B-C connected by a line B feeding a load at the receiving end C. The ratings and
parameter values of the components are:

Transformer A-B: 500V/1.5kV, 9.6kVA, leakage reactance = 5%

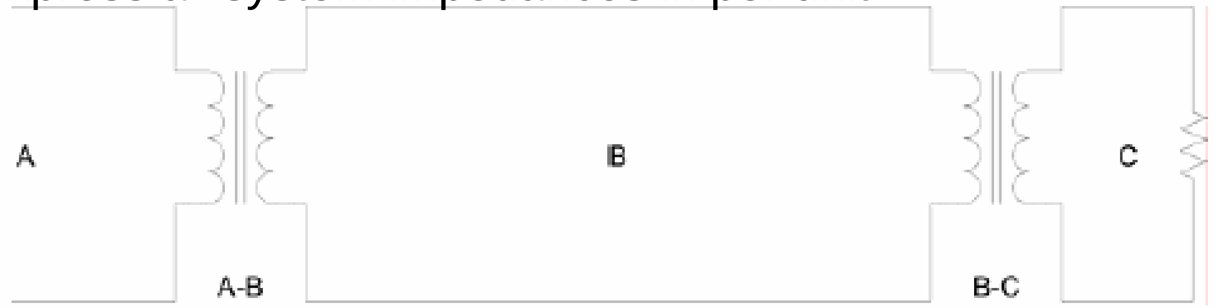
Transformer B-C: 1.2kV/120V, 7.2kVA, leakage reactance = 4%

Line B: series impedance = (1.5+*j*3.0)

Load C: 120V, 6kVA at 0.8 power-factor lagging

a) Determine the value of the load impedance in ohms and the actual ohmicimpedances of the two transformers referred to both their primary and secondary

b) Choosing 1.2 kV as the voltage base for circuit B and 10 kVA as the systemwide kVA base, express all system impedances in per unit.



電力系統之短路容量(KVAs)

$$VAs = I_{Sy} \times V_b = \frac{V_b}{Z_s} \times V_b = \frac{V_b^{\ 2}}{Z_s}$$

$$Z_s = \frac{(V_b)^2}{VA_s} \qquad Z_b = \frac{(V_b)^2}{VA_b}$$

$$Z_{spu} = \frac{Z_s}{Z_b} = \frac{KVA_b}{KVA_s}$$

台電:

11.4KV供電	250MVA
22.8KV供電	500MVA
69KV供電	1500MVA